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## Sponging off of Porifera: New Species of Cryptic Dorid Nudibranchs (Mollusca, Nudibranchia) from the Tropical Indo-Pacific

by

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Two new species of *Asteronotus* are described from the Indo-Pacific tropics. *Asteronotus mimeticus* sp. nov. is described from specimens collected in the Philippines, Palau, Australia, and Papua New Guinea. *Asteronotus spongicolus* sp. nov. is described from the three localities in Tanzania and one in northern Queensland, Australia. Both species are remarkably cryptic on their prey sponges. *Asteronotus mimeticus* is variable in its color and notal ornamentation, depending upon the sponge on which it is feeding. Both species differ from the only recognized species in the genus, *A. cespitosus* (van Hasselt, 1824) in their smaller body size, lack of regular ridges and rows of tubercles and differences in the radular morphology and reproductive system. In *A. cespitosus* the outermost radular tooth is elongate while in the two new species the outermost tooth is reduced to an ovoid plate. The accessory gland of *A. cespitosus* is regular in shape with a straight stylet while in the two new species the accessory gland is irregularly shaped with a curved stylet. *Asteronotus mimeticus* has a rounded body shape while *A. spongicolus* is more elongate and ovoid. In *A. mimeticus*, the inner radular teeth are usually devoid of denticles, but may rarely have 1–2 additional denticles on the outer side of the inner 14 radular teeth. In *A. spongicolus* the innermost tooth has 1–2 denticles on its inner side and the succeeding 7–11 teeth have 1–2 denticles on the outer side of the tooth. The outermost teeth of *A. mimeticus* are rounded ovoid plates while those of *A. spongicolus* are more quadrangular with an acute apex. The reproductive system of *A. mimeticus* has a bursa copulatrix that is smaller than the receptaculum seminis while in *A. spongicolus* the receptaculum is larger than the bursa. The genital atrium of *A. mimeticus* is shorter and narrower than that of *A. spongicolus*. The accessory spine of *A. mimeticus* has a narrow base and is gradually curved while in *A. spongicolus* the spine has a broad base with a sharply curved apex.

Recent field studies at several localities around the Indo-Pacific tropics have yielded numerous individuals of dorid nudibranchs that are cryptic on large, foliose sponges inhabiting shallow water coral reef communities. Anatomical studies indicate that these dorids represent two undescribed species of the genus *Asteronotus* Ehrenberg, 1831. The only currently recognized member of this genus is *A. cespitosus* (van Hasselt, 1824). Valdés and Gosliner (2001) have recently reviewed its anatomy and systematic position. The present paper describes the anatomy of these two new species. Type material

is housed in the collections of the California Academy of Sciences (CASIZ) and the Natural History Museum of Los Angeles County (LACM).

### SPECIES DESCRIPTIONS

#### *Asteronotus mimeticus* sp. nov.

Figs. 1A–D; 2; 3; 4; 5; 6A, B

MATERIAL EXAMINED. — HOLOTYPE: CASIZ 157487, Arthur's Rock, Calumpan Peninsula, Batangas Province, Luzon Island, Philippines, 15 m depth, 22 February 1992, T. M. Gosliner. PARATYPES: CASIZ 084294, six specimens, same locality and date as the holotype. LACM 2901, one specimen, same locality and date as the holotype. CASIZ 156622, three specimens, two dissected, Arthur's Rock, Calumpan Peninsula, Batangas Province, Luzon Island, Philippines, 15 m depth, 11 May 2001, T. M. Gosliner. CASIZ 156664, one specimen, Devil's Point, Maricaban Island, Batangas Province, Luzon Island, Philippines, 15 m depth, 10 May 2001, T. M. Gosliner. CASIZ 157492, two specimens, one dissected, Layag Layag, Caban Island, Batangas Province, Luzon Island, Philippines, 15 m depth, 7 May 2001, T. M. Gosliner. CASIZ 157491, one specimen, Layag Layag, Caban Island, Batangas Province, Luzon Island, Philippines, 8 m depth, 7 May 2001, A. Valdés. CASIZ 083709, four specimens, Koala, Calumpan Peninsula, Batangas Province, Luzon Island, Philippines, 28 February 1992, T. M. Gosliner. CASIZ 088127, five specimens, Twin Rocks, Calumpan Peninsula, Batangas Province, Luzon Island, Philippines, 17 m depth, 22 March 1993, T. M. Gosliner. CASIZ 156594, one specimen, Koala, Calumpan Peninsula, Batangas Province, Luzon Island, Philippines, 15 m depth, 12 May 2001, T. M. Gosliner. CASIZ 088155, two specimens, one dissected, 2 km e. of Lighthouse, Dakak, Mindanao Island, Philippines, 20 m depth, 29 March 1993, T. M. Gosliner. CASIZ 086032, one specimen, N. side of Lighthouse, Dakak, Mindanao Island, Philippines, 31 March 1993, T. M. Gosliner. CASIZ 113637, one specimen, dissected, Sullivan's Patches, n. side of Milne Bay, Milne Bay Province, Papua New Guinea, 27 May 1998, T. M. Gosliner. CASIZ 113693, three specimens, one dissected, Tagula Island, Calvados Chain, Louisiade Archipelago, Papua New Guinea, 4 June 1998, T. M. Gosliner. CASIZ 113695, one specimen, Brooker Channel, Calvados Chain, Louisiade Archipelago, Papua New Guinea, 1 June 1998, T. M. Gosliner. CASIZ 109732, two specimens, one dissected, inner side of barrier reef, Babalukes, Koror Municipality, Palau, 23 September 1996, T. M. Gosliner. CASIZ 139593, one specimen, Jemeluk Beach, Amed, Bali, Indonesia, 3 m depth, 31 October, 2000, T. M. Gosliner. OTHER MATERIAL: Australian Museum, AM C115955, one specimen, 21 mm alive, Lizard Island, North Queensland, Australia, 100 m off research lab on patch reef, 3 m depth, on *Carteriospongia* sp., 1 June 1979, J. Bakus and W. B. Rudman.

ETYMOLOGY. — The name *Asteronotus mimeticus* is derived from its resemblance to its sponge prey with which it is cryptically associated.

NATURAL HISTORY. — This species is found abundantly on the undersides of the leafy sponge, *Phyllospongia lamellosa* (Esper, 1799) and a few other foliose demosponges such as *Carteriospongia* sp., where the nudibranchs are cryptically colored on these species of sponges (Fig. 1A–D). The egg mass of this species (Fig. 2) is a flat, tightly coiled spiral of 2–3 whorls. The eggs are relatively large, suggesting that this species may have direct or lecithotrophic rather than plaktotrophic development.

DISTRIBUTION. — This species is known from several localities in the western Pacific Ocean from the Philippine Islands, Palau, Indonesia, Australia (W. B. Rudman, personal communication) and Papua New Guinea (present study).

EXTERNAL MORPHOLOGY. — The living animals (Figs. 1A–D, 2) are oval in shape, 13–30 mm in length. The body color is gray, brown or yellow with scattered opaque white spots on the notum. The notum may be entirely smooth (Figs. 1A, B; 2), or may possess tubercles and a few elongate papillae (Fig. 1C, D). The rhinophores are perfoliate with 6–10 lamellae. There may be brownish pig-

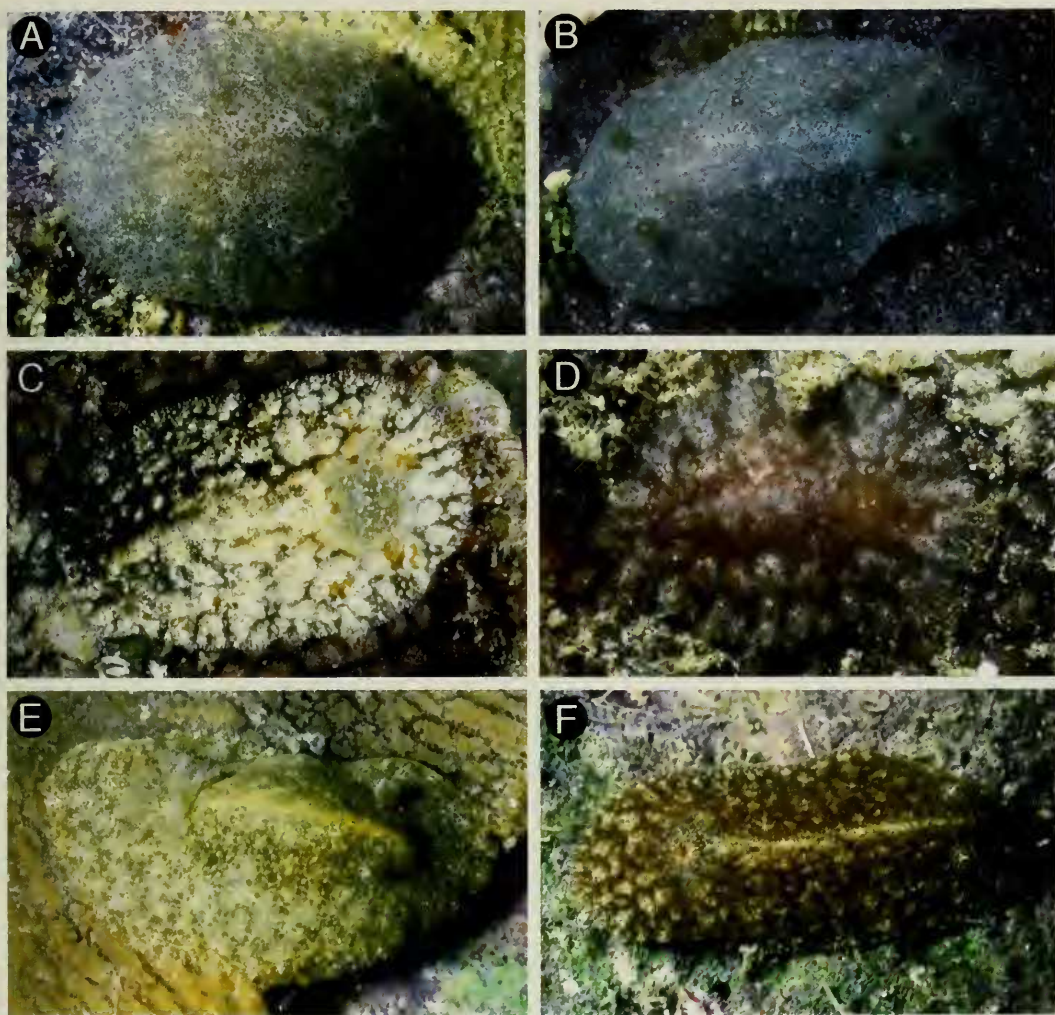


FIGURE 1. Photographs of living animals. A. *Asteronotus mimeticus*, brown smooth specimen from Luzon, Philippines (CASIZ 156664); B. *Asteronotus mimeticus*, gray smooth specimen from Mindanao, Philippines (CASIZ 088155); C. *Asteronotus mimeticus*, papillated specimen from Luzon, Philippines (CASIZ 084294); D. *Asteronotus mimeticus*, tuberculated specimen from Luzon, Philippines (CASIZ 156622); E. *Asteronotus spongicolus*, specimen from northern Tanzania (CASIZ 099293); F. *Asteronotus spongicolus*, specimen from southern Tanzania (CASIZ 099294). Photographs by T. M. Gosliner.

ment on the base and middle region: the apex is opaque white. The two rhinophoral sheaths have 7–8 lobes along their margin. The gill consists of 5–6 tripinnate branchial leaves, which are the same color as the body and may bear scattered opaque white spots. The gill pocket contains six distinct lobes. The foot is broad and generally the same color as the rest of the body. Anteriorly it is bilabiate and notched. An elongate, digitiform oral tentacle is present laterally on either side of the labial region and mouth.

**LABIAL CUTICLE AND RADULA.** — The buccal mass is muscular throughout. The anterior end of the buccal mass contains the labial cuticle, which is thin throughout its length and is devoid of any thickening, armature or rodlets. The radula is wide with numerous hamate teeth. The radular formula is  $51 \times 28.0.28$  (CASIZ 156622),  $42 \times 26.0.26$  (CASIZ 156623),  $48 \times 32.0.32$  (CASIZ 084294) and  $28 \times 32.0.32$  (CASIZ 113693) in four specimens examined. The inner lateral teeth (Figs. 3A, B; 4A,



FIGURE 2. *Asteronotus mimeticus* from the Philippines with the egg mass, photograph by A. Valdés.

C) are relatively short with a broad base and a curved primary cusp. These teeth lack denticles with the exception of a specimen from Papua New Guinea (Fig. 4C) (CASIZ 113693) where the inner 14 teeth bear 1–2 small, triangular denticles along the outer side of the cusp. There is an abrupt transition between the inner and middle lateral teeth. The middle lateral teeth (Fig. 3C) are larger and more elongate than the inner ones and lack denticles in all specimens examined. The outer lateral teeth are elongate and curved (Figs. 3D; 4B, D) with the exception of the outermost tooth, which is reduced to an ovoid plate.

REPRODUCTIVE SYSTEM. — The hermaphroditic reproductive system is triaulic (Fig. 5). The ampulla is elongate and slightly convoluted. It narrows and divides into the vas deferens and oviduct. The vas deferens expands into a short, wide prostate that consists of two distinct portions. The prostate abruptly narrows distally into an elongate, muscular, ejaculatory portion. This muscular segment expands as it enters the relatively short common genital atrium. An irregular accessory gland is present and has a muscular duct that enters the atrium between the deferent duct and the vagina. Within the muscular base of the accessory gland there is an elongate, somewhat-curved cuticular spine (Fig. 6A, B). The vaginal duct is thin and elongate and enters the large, spherical bursa copulatrix. Adjacent to

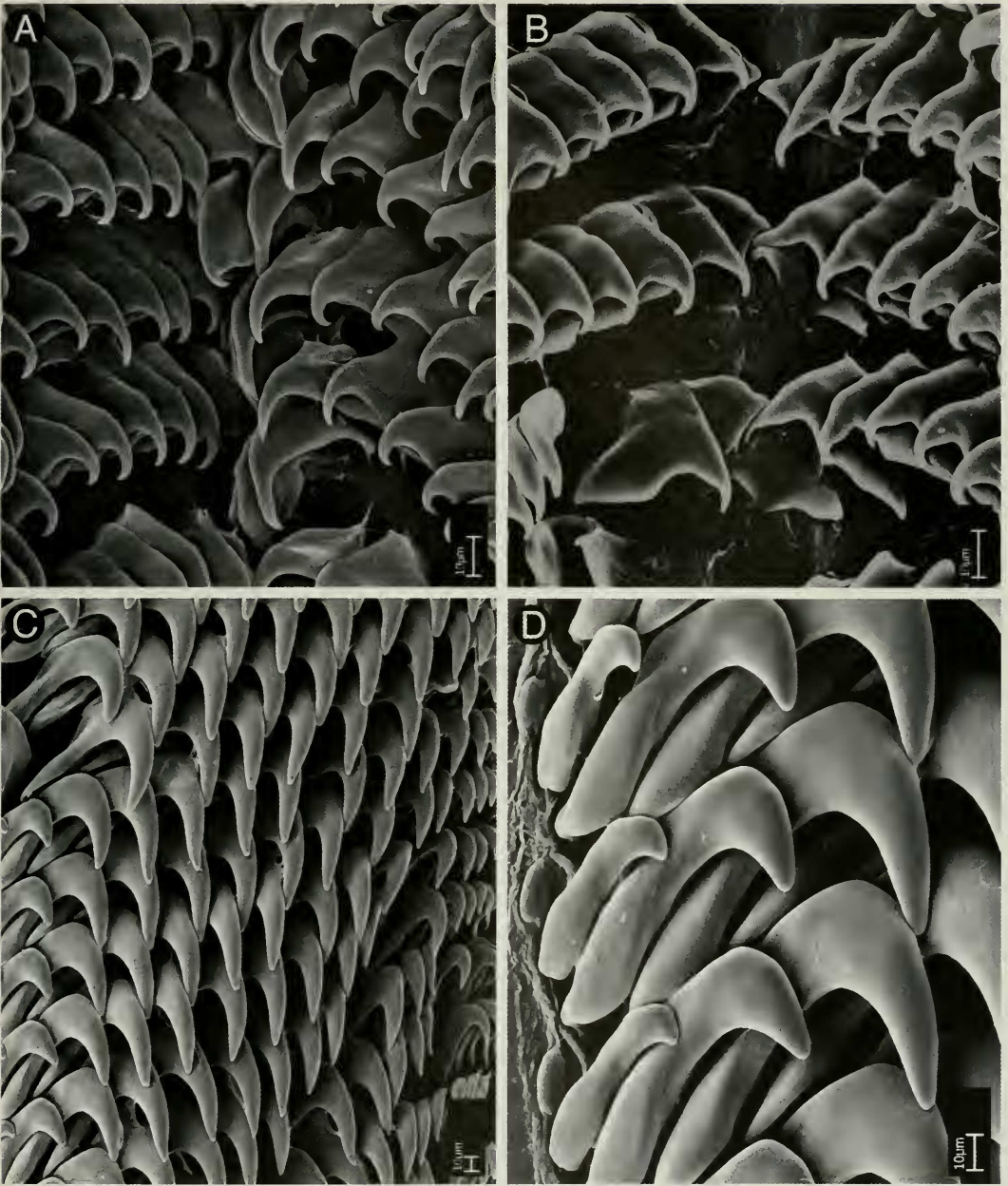


FIGURE 3. Scanning electron micrographs of the radula of *Asteronotus mimeticus*. A. Innermost lateral teeth of a smooth specimen from the Philippines (CASIZ 156623); B. Innermost lateral teeth of a tuberculated specimen from the Philippines (CASIZ 156622); C. Mid-lateral teeth of a tuberculated specimen from the Philippines (CASIZ 156622); D. Outermost teeth of a tuberculated specimen from the Philippines (CASIZ 156622).

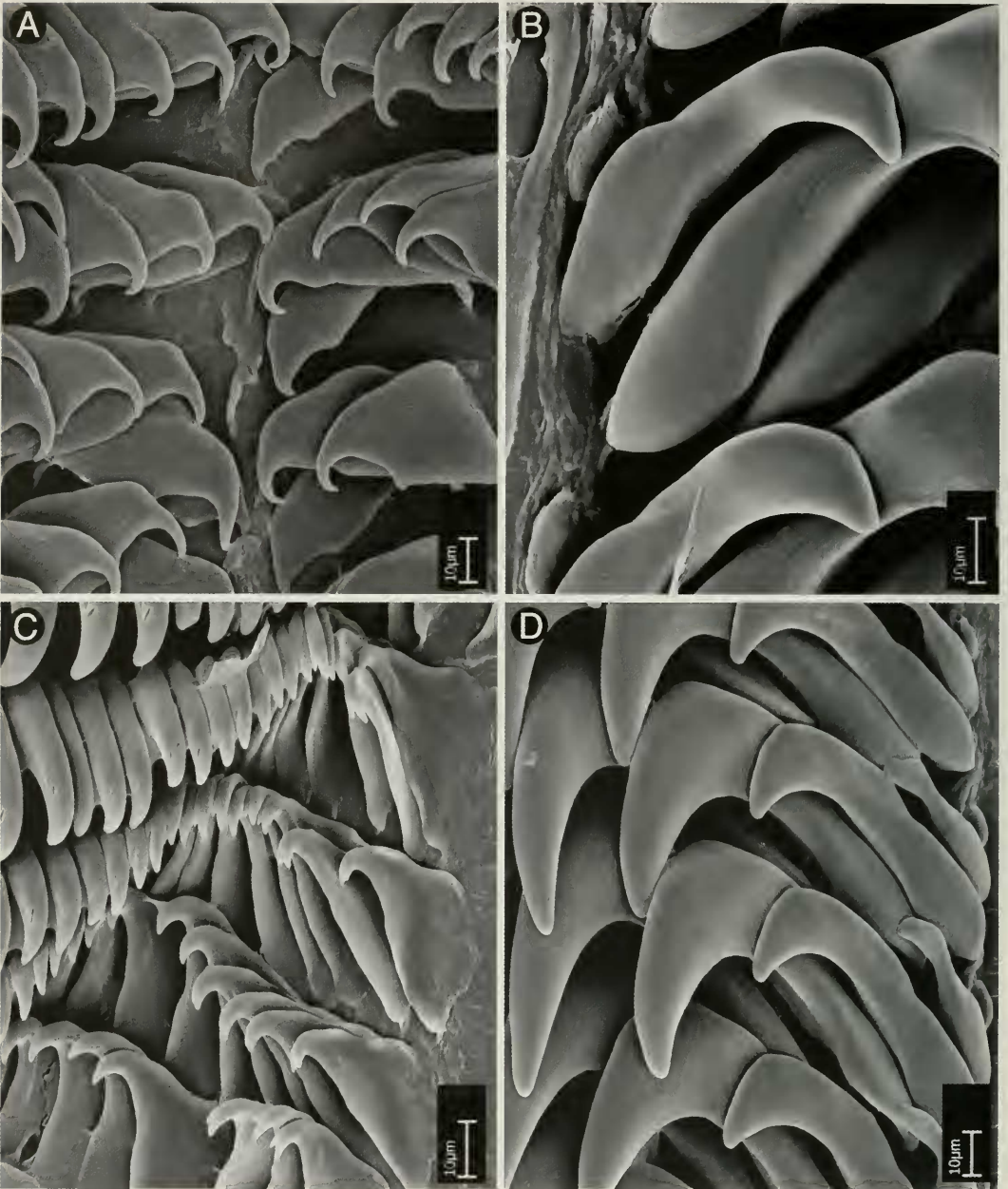


FIGURE 4. Scanning electron micrographs of the radula of *Asteronotus mimeticus*. A. Innermost lateral teeth of a papillated specimen from the Philippines (CASIZ 084294); B. Outermost teeth of a papillated specimen from the Philippines (CASIZ 084294); C. Innermost lateral teeth of a smooth specimen from Papua New Guinea (CASIZ 113693); D. Outermost teeth of a smooth specimen from Papua New Guinea (CASIZ 113693).

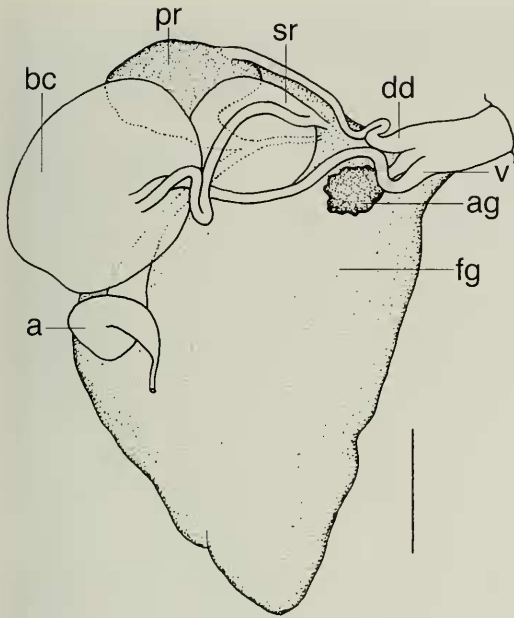


FIGURE 5. Reproductive system of *Asteronotus mimeticus* (CASIZ 084294), scale bar = 1 mm. Abbreviations: a, ampulla; ag, accessory gland; bc, bursa copulatrix; dd, deferent duct; fg, female glands; pr, prostate; sr, seminal receptacle; v, vagina.

North Queensland, Australia, 100 m off research lab on patch reef, 3 m depth, on *Carteriospongia* sp., 1 June 1979, J. Bakus and W. B. Rudman.

ETYMOLOGY. — The name *Asteronotus spongicolus* is derived from its association with lobate, foliose sponges.

NATURAL HISTORY. — This species is found abundantly on the undersides of the leafy lobate sponge, *Carteriospongia* sp., where it is cryptically colored. *Asteronotus spongicolus* is found in shallow water of 1–3 m depth.

DISTRIBUTION. — This species is known from three localities in Tanzania, from Zanzibar and north of Dar es Salaam south to the Mtwara region near the Mozambique border and northern Queensland, Australia (W. B. Rudman, personal communication).

EXTERNAL MORPHOLOGY. — The living animals (Fig. 1E,F) are elongate, ovoid in shape. Living specimens are 10–35 mm in length. The body color is yellowish green to brown with scattered, opaque white and dark brown to black spots on the notum. There is a medial longitudinal line of lighter pigment that extends from immediately anterior to the rhinophores to the anterior edge of the branchial pocket. The notum may be entirely smooth or may possess a few slightly elevated tubercles. The rhinophores are perfoliate with 10 lamellae. Opaque white spots are present on the base and middle region of the rhinophores and the apex is also opaque white. The two rhinophoral sheaths have 8 lobes along their margin. A concentration of opaque white spots is present along the margin of either rhinophoral sheath. The gill consists of 5–6 tripinnate branchial leaves, which are the same color as the body and bear many scattered, opaque white spots. The gill pocket contains six distinct lobes and also bears a concentration of opaque white spots along its margin. The foot is broad and generally the same color as the rest of the body. Anteriorly it is bilabiate and notched. An elongate, digitiform oral tentacle is present laterally on either side of the labial region and mouth.

the proximal end of the vagina and also emerging from the bursa is another elongate duct that joins the bursa with the smaller, thick-walled receptaculum seminis. Also joining this duct at the base of the receptaculum is the short uterine duct.

*Asteronotus spongicolus* n. sp.

Figs. 1E, F; 6C; 7; 8

MATERIAL EXAMINED. — HOLOTYPE: CASIZ 099389, one specimen, Uroa, 3 km N. of Uroa Beach Hotel, east coast of Zanzibar, Tanzania, 2 m depth, 10 November 1994, T. M. Gosliner. PARATYPES: LACM 2902, one specimen, same locality and date as holotype. CASIZ 099293, six specimens, three dissected, Mbudya Island, off Kunduchi Beach, Pwani Region, N. of Dar es Salaam, Tanzania, 1–3 m depth, 27 October 1994, T. M. Gosliner. CASIZ 099394, two specimens, one dissected, Mana Huanja Island, Mtwara Region, Tanzania, 1 November 1994, T. M. Gosliner. OTHER MATERIAL: Australian Museum, AM C115954, one specimen, 28 mm alive, Lizard Island,

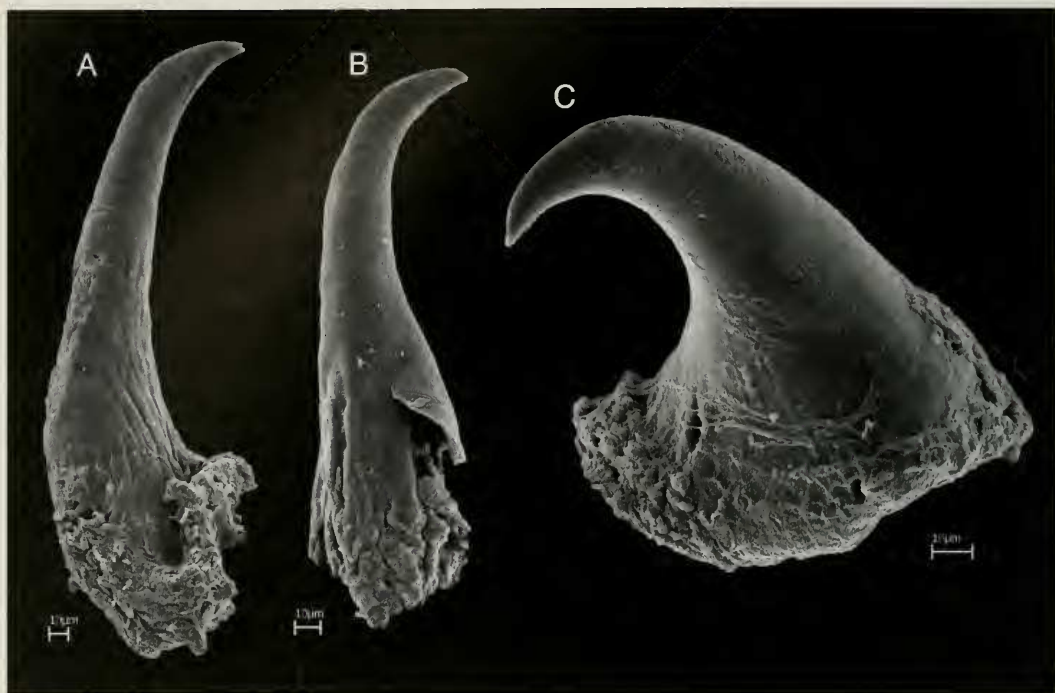


FIGURE 6. Scanning electron micrographs of the copulatory spines. A. *Asteronotus mimeticus* smooth specimen from the Philippines (CASIZ 084294). B. *Asteronotus mimeticus*, tuberculated specimen from the Philippines (CASIZ 15622); C. *Asteronotus spongiculus*, smooth specimen from Tanzania (CASIZ 099293).

**LABIAL CUTICLE AND RADULA.** — The buccal mass is muscular throughout. The anterior end of the buccal mass contains the labial cuticle, which is thin throughout its length and is devoid of any thickening, armature or rodlets. The radula is wide with numerous hamate teeth. The radular formula is  $43 \times 30.0.30$  (CASIZ 099293) and  $52 \times 27.0.27$  (CASIZ 099394) in two specimens examined. The inner lateral teeth (Fig. 7A,B) are relatively short with a broad base and a curved primary cusp. The innermost teeth have 1–2 denticles on the inner side of the primary cusp. The succeeding 7 teeth have 1–2 small, triangular denticles on the outer side of the cusp. There is an abrupt transition between the inner and middle lateral teeth. The middle lateral teeth (Fig. 7C) are larger and more elongate than the inner ones and lack denticles in both specimens examined. The outer lateral teeth are elongate and curved (Fig. 7D) with the exception of the outermost tooth, which is reduced to a quadrangular plate with an acute anterior apex.

**REPRODUCTIVE SYSTEM.** — The hermaphroditic reproductive system is triaulic (Fig. 8). The ampulla is thick, elongate and slightly curved. It narrows and divides into the vas deferens and oviduct. The vas deferens expands into a short, wide prostate that consists of two distinct portions. The prostate abruptly narrows distally into an elongate, muscular, ejaculatory portion. This muscular segment expands as it enters the relatively long, wide common genital atrium. An irregular accessory gland is present and has a long convoluted muscular duct that enters the atrium between the deferent duct and the vagina. Within the muscular base of the accessory gland is a short, strongly curved cuticular spine with a broad base (Fig. 6C). The vaginal duct is thin and elongate and enters the small, spherical bursa copulatrix. Adjacent to the proximal end of the vagina and also emerging from the bursa is another elongate duct that joins the bursa with larger, thick-walled receptaculum seminis. Also joining this duct at the base of the receptaculum is the short uterine duct, which then enters the female gland mass.



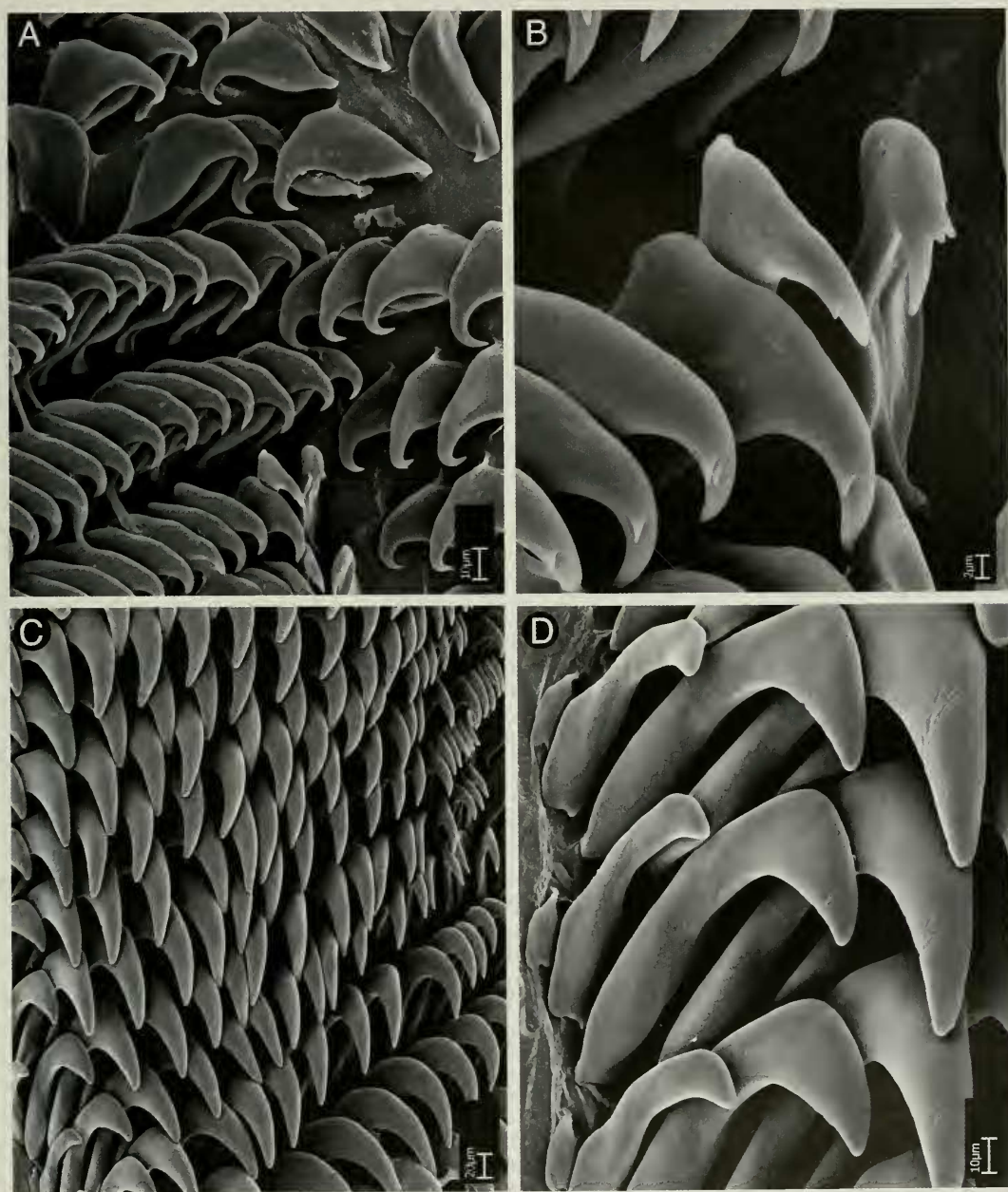


FIGURE 7. Scanning electron micrographs of the radula of *Asteronotus spongicolus* (CASIZ 099293). A. Innermost lateral teeth; B. Detail of the denticles on the innermost lateral teeth; C. Mid-lateral teeth; D. Outermost lateral teeth.

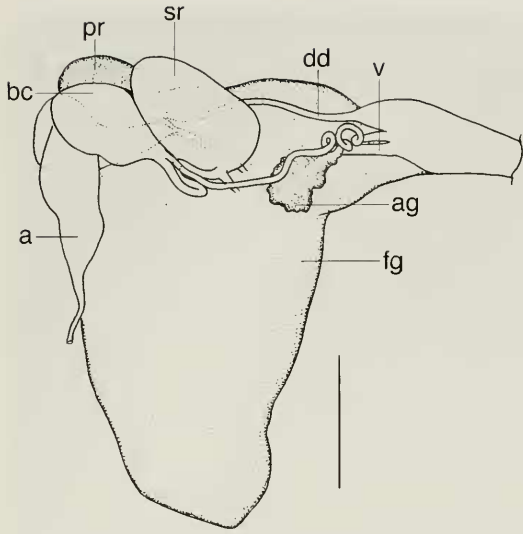


FIGURE 8. Reproductive system of *Asteronotus spongicolus* (CASIZ 099293), scale bar = 1 mm. Abbreviations: a, ampulla; ag, accessory gland; bc, bursa copulatrix; dd, deferent duct; fg, female glands; pr, prostate; sr, seminal receptacle; v, vagina.

Eliot, 1908 and *P. rehderi* Marcus and Marcus, 1970, have been assigned to this genus. These species all have interconnecting ridges on the notum and numerous denticulate radular teeth. *Peronodoris rehderi* has a large muscular accessory structure that contains a spine (Marcus and Marcus 1970). Species of *Asteronotus* have a glandular accessory structure with a muscular duct that contains a spine. This appears to represent a significant distinction between the taxa, but further clarification of this apparent difference must await rediscovery of species of *Peronodoris* to confirm these anatomical features.

The genus *Asteronotus* is distinguished by several autapomorphies. It has a gill with a lobed branchial pocket, a short prostatic portion of the vas deferens and an accessory gland that bears a single spine within a muscular structure. The two new species described here share all of these characteristics with *A. cespitosus*, but differ from this species in several regards. Both species differ from *A. cespitosus* in their smaller body size, lack of regular ridges and rows of tubercles and differences in the radular morphology and reproductive system. In *A. cespitosus* the outermost radular tooth is elongate while in the two new species the outermost tooth is reduced to an ovoid plate. The accessory gland of *A. cespitosus* is regular in shape with a straight stylet, whereas in the two new species the accessory gland is irregularly shaped with a curved stylet. *Asteronotus mimeticus* has a rounded body shape while *A. spongicolus* is more elongate and ovoid. In *A. mimeticus*, the inner radular teeth are usually devoid of denticles, but may rarely have 1–2 additional denticles on the outer side of the inner 14 radular teeth. In *A. spongicolus* the innermost tooth has 1–2 denticles on its inner side and the succeeding 7–11 teeth have 1–2 denticles on the outer side of the tooth. The outermost teeth of *A. mimeticus* are rounded ovoid plates, whereas those of *A. spongicolus* are more quadrangular with an acute apex. The reproductive system of *A. mimeticus* has a bursa copulatrix that is larger than the receptaculum seminis, whereas in *A. spongicolus* the receptaculum is larger than the bursa. The genital atrium of *A. mimeticus* is shorter and narrower than that of *A. spongicolus*. The accessory spine of *A. mimeticus* has a narrow base and is gradually curved, whereas in *A. spongicolus* the spine has a broad base with a sharply curved apex.

## DISCUSSION

The anatomy and systematics of the dorid nudibranch genus *Asteronotus* has been well studied by recent workers (Kay and Young 1970; Edmunds 1971; Valdés and Gosliner 2001). All of these authors describe the anatomy of *A. cespitosus* and consider this as the only valid species within the genus. Valdés and Gosliner (2001) conducted a phylogenetic analysis of caryophyllidia-bearing dorids and concluded that *Asteronotus* is the sister taxon of *Halgerda* Bergh, 1880. Together these two taxa are the sister group of the caryophyllidia-bearing dorids.

Valdés and Gosliner (2001) discussed the possible synonymy of *Peronodoris* Bergh, 1904, with *Asteronotus*. No definitive synonymy could be made owing to the lack of type material for the type species of *Peronodoris*, *P. cancellata* Bergh, 1904. Since Bergh's 1904 description, two other species, *P. denticulata*

Many species of sponge-feeding dorid nudibranchs are known to exhibit special resemblance to their prey sponges (Gosliner and Behrens 1990). This crypsis has been best demonstrated for temperate nudibranchs and has not been as well documented for tropical taxa. This paper describes crypsis for two new species of *Asteronotus*. In *A. mimeticus* color pattern and texture vary considerably and reflect the variability of the sponge prey species fed upon by this species. Not only are the adult nudibranchs of this species cryptic, but the egg mass is also cryptically colored on the prey sponge. Most dorid nudibranchs have an egg mass morphology, in which the edge of the mass is attached by one edge of the egg ribbon and the remaining portion is free and well elevated from the surface. In *A. mimeticus*, the egg mass is attached directly to the sponge by its widest margin, minimizing the visibility of the egg mass. The egg mass morphology of *A. spongicolus* remains unknown. Nevertheless, the color pattern and texture of these two species make them remarkable examples of special resemblance in tropical dorid nudibranchs.

#### ACKNOWLEDGMENTS

We thank Kit Stewart for supporting the field work undertaken in Tanzania, the Christensen Research Institute for supporting work in the Madang area of Papua New Guinea and the Coral Reef Research Foundation for supporting field work in Milne Bay and the Louisiade Archipelago in Papua New Guinea and Palau. The research on this material and production of this paper was supported by the National Science Foundation through the PEET Grant DEB-9978155 (Phylogenetic systematics of dorid nudibranchs). Yolanda Camacho, Shireen Fahey, Mike Miller, Vic Smith, Yvonne Vallès and Gary Williams kindly assisted with field collections. Bill Rudman, kindly provided photographs and additional records of both species from Australia.

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